THERMOFORMED APPARATUS HAVING A COMMUNICATIONS DEVICE

BACKGROUND OF THE INVENTION

[0001] This invention generally relates to thermoformed apparatuses and more particularly to a polymeric pallet or container having a communications device.

[0002] The 48 inch by 40 inch wood pallet is an integral part of North America's distribution system, and is involved in one way or another in the movement of a significant proportion of all goods bought and sold. According to Material Handling Engineering (October 1999), page 16, the U.S. Forest Service estimates there are 1.9 billion wooden pallets in America. Approximately 400 million new pallets are needed each year. 175 million of these are pallets repaired for reuse by industry. Therefore, roughly 225 million new wooden pallets enter the supply chain each year. The standard 48 inch by 40 inch wood pallet makes up a significant proportion of the total number of wood pallets within the over-all distribution system.

[0003] U.S. Forest researchers also found that 225 million wooden pallets are sent to landfills each year. According to CHEP Equipment Pooling Systems, the largest third party pallet leasing company with 94 million wooden pallets, the average 48 inch by 40 inch wooden pallet weighs between 28 pounds and 65 pounds at the time of manufacture (dry). These traditional wooden pallets range from 48 pounds to 110 pounds in weight (wet) at time of recycling or disposal. Using these figures, approximately 17.8 billion pounds of wood is deposited in

landfills each year. APA, the Engineered Wood Association, estimates that a standard 48 inch by 40 inch style lumber stringer pallet has a three year life. The three year cost for this style of wooden pallet is estimated to be $11.74. A three year life is based on 15-24 trips per year. Conventional wooden pallets have limited residual value at the end of their useful life cycle.

[0004] According to the Grocery Manufacturers of America (hereinafter "GMA"), the largest end-user of traditional 48 inch by 40 inch wooden pallets within the North American distribution system, the current wooden pallet exchange system costs the industry nearly $2 billion to operate in 1991. For example, the trucking industry is unable to optimize semi trailer loading or per-unit transportation costs because GMA style pallets are not capable of true four-way entry. Drivers are required to exchange loaded pallets for empty pallets after delivery, and because of manual pallet handling injuries, workers compensation claims are significant. Grocery distributors are unable to use automated material handling equipment efficiently because unacceptable wooden pallets must be removed from the pallet supply chain. Grocery manufacturers and shippers experience product damage because of design flaws in traditional wooden pallets. Furthermore, unit loading is not evenly distributed with stringer pallet designs, which results in product and packaging damage in transport. Manufacturers must use stronger and costlier packaging because of wooden pallet problems. Wooden pallet sanitation and moisture absorption difficulties affect meat and other food processors. Moreover, general pallet deterioration, manifested by protruding nails and staples, splintered wood and missing stringers, results in significant inefficiencies within the over-all distribution system.

[0005] More and more companies are finding it preferable to employ third-party pallet management services to control the costs and logistics of using wooden pallets. For example, some fruit growers require pallets on a seasonal basis. Wooden pallets may therefore be rented for short or long terms from third parties. Third party service companies offer nationwide access to pools of wooden pallets, have responsibility for collecting and redeploying pallets where they are needed, and keep the pallet pool at a relatively high level of quality to move product through the distribution channel. The pallet tracking and retrieval systems deployed by the third party providers are more elaborate and efficient than other segments within the wooden pallet market. For example, bar code labels have been used to manage the efficiency of conventional pallet assets. A direct line of sight is, however, required by the scanner to read a bar card label. The performance of these systems has been generally unreliable and costly to implement within a wooden pallet environment.

[0006] Conventional Radio Frequency Identification (hereinafter "RFID") systems have also been used but without success for a number of reasons. For instance, there are too many makes and models of 48 inch by 40 inch wooden pallets in the market. Also, a standard protocol has not been advanced. Furthermore, pallet handling procedures, material deterioration, product damage and repair practices require a more robust RFID tag technology than is currently available and wood is not a stable platform for the attachment of many types of RFID tags. Additionally, radio frequencies are absorbed by moisture in wood, which makes tag reads unreliable. Standard harsh operating conditions within

the wooden pallet distribution system, thermal shock, sanitation, flexure, vibration, compressive forces and fork impacts, can cause traditional tag transponder coils to break and fail.

[0007] The velocity at which 48 inch by 40 inch wooden pallets travel through the distribution system is far less than optimum because a significant proportion of wooden pallets are not suitable for transporting goods, damage free. Although 175 million pallets are repaired each year, industry observers claim as many as 70% of all wooden pallets have deteriorated from their original specifications. Unacceptable wooden pallets have to be separated from acceptable wooden pallets, which is time consuming, injurious and wasteful. Accordingly, a far larger pool of wooden pallets is maintained in operation than would otherwise be required under optimum conditions. The traditional 48 inch by 40 inch wooden pallet is therefore tremendously inefficient, costing industry billions of dollars annually. Wooden pallets also have considerable negative societal and environmental impacts because the recourses used to purchase, repair and dispose wooden pallets could be more effectively deployed in other less costly product technology alternatives.

[0008] Accordingly, plastic pallets have been used to replace wood pallets with some degree of success over the past several years. Plastic pallets are known for their longevity and are generally more durable, lighter weight, compatible with automated material handling equipment, easily sanitized and 100 percent recyclable. Conventional plastic pallets, however, suffer from one significant disadvantage in that they cost considerably more than a comparable wooden pallet. Thermoplastic materials constitute a significant proportion of the

total cost of a plastic pallet, and a given amount of relatively expensive polymeric material is required to produce a pallet with a measure of load-bearing strength that is comparable to wooden pallets.

[0009] As another example, U.S. Patent No. 5,986,569 which issued to Mish et al. proposes applying a pressure sensitive tape to the backside of a tag carrier and affixing the carrier to an object. Generally speaking, however, exterior attachment methodologies are not sufficiently robust and durable. Tags affixed to the exterior of the pallet can be damaged through wear and tear, sanitation, fork lift impacts, and the like. Also, U.S. Patent No. 5,936,527 which issued to Isaacman, et al., proposes a "cell" comprising a host transceiver and several local hard lined interrogators that detect local tags. In the Isaacman arrangement, several cells can be networked, which allows any tagged object to be identified from any PC within a multi-cell network.

[0010] It is significant that plastic pallet suppliers have been unable to physically identify, locate and track, in real time, comparatively expensive conventional plastic pallets within networks of distribution. It is one thing to lose a low cost wooden pallet, but it is another to lose an expensive asset. Different technologies have been proposed to attempt tracking of pallet assets within the distribution system, but these proposals have been incomplete with respect to system architectures, protocols and plastic pallet design intent. Bar codes have been used, but these again require a direct line of sight and have therefore been difficult to implement. RFID tags have been placed upon traditional molded pallets to locate and track their positions within the distribution system, but this

type of pallet is so much more expensive than a comparable wooden pallet that the cost justification for implementation is not economical.

[0011] Moreover, it is known that conditions within the operating environment affect the performance of the RFID system. Several U.S. patents disclose protocols, circuitry architectures and other enabling methods for ensuring the interrogator properly communicates with one or more tags within an interrogation zone; these include: 5,229,648 which issued to Shindley et al.; 5,479,416 which issued to Snodgrass et al.; 5,539,775 which issued to Tuttle et al.; 5,583,819 which issued to Roesner et al.; 5,818,348 which issued to Walezak et al.; 5,822,714 which issued to Cato; 5,929,779 which issued to MacLellen et al.; 5,942,987 which issued to Heinrich et al.; 5,955,950 which issued to Gallagher et al.; 5,963,144 which issued to Kruest; and 5,986,570 which issued to Black et al. Still other proposals are offered to overcome the antenna-to-antenna communication difficulties conventionally experienced by tag carriers, such as pallets, as they travel through interrogation fields or portals. The rapidly changing angular geometry of a tag passing through a field or portal results in a diminishing duration and strength of signal transmission, which can produce unreliable tag reading results. The following U.S. Patent Nos. propose solutions to this particular problem: 5,661,457 which issued to Ghaffari et al.; 5,708,423 which issued to Ghaffari et al.; 5,686,928 which issued to Pritchett et al.; 5,995,898 which issued to Tuttle; and 5,999,091 which issued to Wortham.

SUMMARY OF THE INVENTION

[0012] In accordance with the present invention, an apparatus has a communications device associated therewith. In another aspect of the present invention, a pallet is made from thermoformed polymeric sheets with an attached communications device. A further aspect of the present invention provides a radio frequency identification device attached to an apparatus. In still another aspect of the present invention, a communications device is incorporated into one or more sheets of a pallet or other container prior to forming. Methods of making and using a thermoformed pallet and container, having a communications device, are also provided.

[0013] The pallet of the present invention is advantageous over traditional constructions in that the present invention enhances protection of the communications device within the pallet in order to increase durability and reliability of the identification system. The locational placement of the communications device within the pallet allows for increased ability to track and identify polymeric pallets or other removable part transportation and storage containers, carriers, tanks or structures. Furthermore, the present invention is advantageous by incorporating the communications device into the pallet during the process of manufacturing the pallet. This advantageously allows for the information contained in the device to vary the pallet manufacturing machinery and the manufacturing process. Moreover, the present invention increases the economical feasibility for using traditionally more expensive polymeric pallets in the distribution chain through increased durability, tracking, recyclability and optimized manufacturing processes.

[0014] More specifically, the apparatus of the present invention advantageously employs a stronger plastic pallet that is lower cost, lighter weight, one hundred percent recyclable and wirelessly networked to a data center developed to efficiently manage the transportation of goods, damage free, throughout the distribution system. Furthermore, the present invention provides an economically viable plastic pallet replacement for traditional wooden pallets. The present invention also fulfills the need for a system that can be used to accelerate the velocity of pallet movement within the distribution system; hence, the present invention advantageously reduces the over-all number of plastic pallets within the distribution system. A suitable plastic pallet coupled to an RFID system and the methods of the present invention enable the pallets to be more effectively managed according to pre-selected system capabilities, objectives and cost constraints, while at the same time reducing the societal burden and environmental impact of conventional wooden pallets. Additional advantages and features of the present invention will become apparent from the following description and appended claims, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Figure 1 is a perspective view showing a preferred embodiment of a thermoformed pallet having a radio frequency device of the present invention;

[0016] Figure 2 is a fragmentary perspective view showing a twin sheet variation of the present invention pallet;

[0017] Figure 3 is a perspective and fragmentary view showing a second variation of the present invention pallet;

[0018] Figure 4 is a perspective view showing the radio frequency device employed in the present invention pallet;

[0019] Figures 5-7 are diagrammatic views showing the manufacturing process employed with the present invention pallet;

[0020] Figure 8 is a diagrammatic perspective view showing the orientation of one radio frequency device arrangement incorporated into the present invention pallet;

[0021] Figure 9 is a diagrammatic view showing the manufacturing process employed with the present invention pallet;

[0022] Figures 10-12 are cross sectional views showing various radio frequency device locations within the present invention pallet;

[0023] Figure 13 is a diagrammatic view showing the interaction between an interrogator and the radio frequency device employed with the present invention pallet;

[0024] Figure 14 is a top elevational view showing an exemplary radio frequency device orientation employed with the present invention pallet;

[0025] Figure 15 is a diagrammatic view showing the interaction between the interrogator and radio frequency device employed with the present invention pallet;

[0026] Figure 16 is an exploded perspective view showing an interrogator incorporated into an alternate embodiment of the present invention pallet;

[0027] Figure 17 is a cross sectional view showing replacement of a battery for the alternate embodiment of the present invention pallet;

[0028] Figure 18 is a flow chart showing another preferred embodiment of the present invention pallet;

[0029] Figure 19 is a diagrammatic view showing another preferred embodiment manufacturing process employed with the present invention pallet;

[0030] Figure 20 is a perspective view showing the present invention pallet of Figure 19;

[0031] Figure 21 is a fragmentary side elevational view showing the present invention pallet of Figure 20;

[0032] Figure 22 is a cross-sectional view of a preferred embodiment tank container of the present invention;

[0033] Figure 23 is a diagrammatic view showing another preferred embodiment tank container of the present invention; and

[0034] Figure 24 is an exploded perspective view showing an alternate embodiment renewable power supply device employed in the present invention apparatus.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0035] Referring to Figures 1-3, the preferred embodiments of a pallet apparatus **2** of the present invention employs a nesting pallet **4** and a communications device, such as a radio frequency identification device **16**. Nesting pallet **4** has downwardly extending pallet legs **6** which are receivable in pallet pockets **8** of an adjacent pallet to provide a nesting configuration for

consolidated storage and transportation. Pallet **4** is made of a plurality of polymeric plastic sheets thermoformed into a single article. Pallet **4** includes a top plastic sheet **10** and a bottom plastic sheet **12**. This arrangement is referred to as a twin sheet construction. In one preferred embodiment, plastic sheet **14**, shown in Figure 3, is sandwiched between sheets **10** and **12**, in what is referred to as a triple sheet construction. One advantage of a triple sheet construction is that the same load bearing strength of a twin sheet construction can be provided with a much lower measure of relatively expensive plastic in a triple sheet construction. Therefore, depending upon the criteria of the end-user, triple sheet constructions can be used to provide either a lower cost or a stronger pallet **4**. The present invention pallet **4** can be made in accordance with U.S. patent application Ser. No. 09/377,792, entitled "Triple Sheet Thermoforming Apparatus, Methods and Articles" which was filed on August 20, 1999 by S. Muirhead; this is incorporated by reference herein. In summary, this method of triple sheet thermoforming provides the same measure of load bearing strength with twenty-five percent to fifty percent less plastic material than current state of the art twin sheet thermoformed pallets. However, twin sheet thermoformed pallets characterized by U.S. Patent Nos. 4,428,306 to Dresen et al., 5,638,760 to Jordan et al., or 5,676,064 to Shuert, can be used to practice certain aspects of the invention; these patents are incorporated by reference herein. A triple sheet thermoformed pallet is preferred because it provides a higher measure of strength for the given measure of plastic used by a twin sheet pallet, and is therefore more economically fulfilling the need for a low cost alternative to wooden pallets.

[0036] The RFID system is minimally composed of three components including an interrogator (reader or exciter), tag devices **16**, and a host computer. The tag is alerted by a radio frequency wave transmitted by the interrogator to return a data message by arrangement. The information stored in memory is thus transmitted back to the interrogator. Information received by an interrogator is used by a host computer to provide a reliable and a secure architecture that meets predetermined performance requirements. In passive RFID systems, the RF field generates voltage that is rectified to power the tag. In active RFID systems, a battery is the source of a tag's power supply. Both passive and active RFID devices may be embedded within the structure of the preferred plastic pallet.

[0037] Radio frequency identification tags and interrogators can be made in accordance with the following U.S. Patent Nos.: 6,027,027 entitled "Luggage Tag Assembly" which issued to Smithgall on February 22, 2000 and 6,013,949 entitled "Miniature Radio Frequency Transceiver" which issued to Tuttle on January 11, 2000. Both of these patents are incorporated by reference herein.

[0038] RFID device **16** is encapsulated between the sheets forming pallet **4**. In general, thermoplastic resins are extruded through a machine that produces a selective sheet or web of heat deformable plastic. As the pre-formed sheet or web travels through the extruder, one or more surfaces of the sheet receives one or more RFID tags. This may be done automatically or manually such that the tag is located on the plastic according to predetermined criteria corresponding to a select molding position upon the thermoforming tooling. The sheet thus tagged moves through a thermoforming machine that molds the sheet into a finished

pallet. The tag or tags are sandwiched between the sheets of plastic forming the pallet at predetermined locations. In this manner, the tag is embedded, isolated, protected and contained in a fluid tight plastic barrier that is resilient, long lasting and not externally, physically visible. In order to ensure that the RFID device is not damaged in the thermoforming process of preference, a high temperature RFID device methodology, such as that described in U.S. Patent No. 5,973,599 which issued to Nicholson et al., may be used; this patent is also incorporated by reference herein. The location of the device within the pallet is selected for system requirements. A plurality of locations can be used by cross-referencing machine and extrusion direction dimension references upon the plastic sheet with their counter part locations upon the properly thermoformed article. Thus, through such registration techniques, a consistent location for positioning the tag upon the sheet relative to its selected location in the finished part can be repeated with a high degree of certainty. In more detail, molded-in structures of the plastic pallet may be adapted to further protect the RFID device from flexural and compressive forces that may other wise damage the device.

[0039] RFID device **16** is part of a system in which data about pallet **4** is stored for retrieval according to system criteria. The advantage of encapsulating RFID device **16** within the structure pallet **4** is so that device **16** is protected from the harsh environment that pallet **4** must operate within.

[0040] There are a number of methods that can be used to insert RFID device **16** within thermoformed pallet **4.** In one embodiment, RFID device **16** is a passive RFID tag **18**. An example of such a passive tag **18** is shown in Figure **4**. Tag **18** includes an antenna coil **20**, modulation circuitry **22** and a micro-memory

chip or integrated circuit **24**. Tag **18** is ultra thin, and in the order of 1 and 1/2 square inches. A plurality of tags **18** are normally placed upon a polymer tape substrate by the tag manufacturer and delivered on reels for integration into a manufacturing process.

[0041] A plastic sheet is heated to a deformable temperature before it is molded by differential vacuum pressure over a mold. Intervention is required to integrate tag **18** into the thermoforming process in order to minimize stretching and heat deformation of the PET substrate. As is shown in Figures 4-6, the first means of intervention includes depositing coil **20**, circuitry **22** (composed of printable conductive ink) and memory chip **24** upon a flexible film substrate **26.** Substrate **26** is a plastic material that has a high heat deflection capability of > 600°F, such as Rodgers Engineering's electrical grade HT 12-1024 resin. After tag **18** components are deposited onto substrate **26**, a film substrate **28** of substantially the same construction is laminated over substrate **26** with a suitable high temperature resistant adhesive **30** therebetween to provide a double layered substrate assembly **32**. A first pressure sensitive, double sided film **36a** is then applied to substrate assembly **32** on the substrate side. Substrate assembly **32** is subsequently sliced or severed such that individual tags **18a** are produced. Tags **18** are separately and possibly sequentially deposited onto a paper or plastic carrier **34** with a single sided, pressure sensitive adhesive film **36b**. Plastic carrier **34** is wound around a hub **38** to produce a reel **40** that includes a plurality of tags **18** that adhered to the surface of a plastic sheet by way of first adhesive film **36a**.

[0042] This arrangement produces a tag construction that is resistant to deformation under the short-term and high heat environment of the thermoforming process. Substrate **32** of tag **18** will not significantly stretch as the attached sheet **62** is deformed over a three dimensional molding surface. Moments of shear at the location of tag **18** will also be deflected through movement of adhesive film **36a**. Adhesive **30** will deflect compression upon the memory chip by providing a compression buffer (thickness) equal to the elevation of memory chip **24**. In this manner, tag **18** is developed to sustain the rigors of thermoforming.

[0043] Another alternate variation of the communications device in the structure of the pallet provides a power supply, an antenna, a radio frequency transmitter, a radio frequency receiver, a digital signal processor, a pallet information memory chip set, a pallet identification reader card, and circuitry. The memory chip set controls the function of the communicator and the identification reader card identifies the communicator and pallet. The communications device will thereby remotely communicate with an external interrogator in a wireless manner, such as by cellular telephone types of transmissions. This is used to instruct the interrogator to then query tags on or in the pallet or container. The interrogator also includes a power supply, an antenna, a radio frequency transmitter, a radio frequency receiver, a data processing micro-controller and circuitry.

[0044] Referring to Figure 7, an X – Y gantry **42** is positioned along the path traveled by a web **44** of plastic material produced by the sheet extrusion machine (not shown). Gantry **42** cooperates with a programmable logic controller

(hereinafter "PLC") **46** that is connected to a local area networked personal computer (hereinafter "LAN PC") **48**. Gantry **42** has a linear high-speed indexer **50** that travels horizontally back and forth according to instructions from PLC **46**. Indexer **50** further has a reel **40** (see Figure 6)-to-reel **52** winder apparatus **54** with a vertical press **56**. As web **44** travels through gantry **42**, indexer **50** travels to a pre-defined location **58**, winder apparatus **54** meters reel **40** forward, carrying tag **18** into vertical alignment with press **56**. Press **56** is instructed to travel vertically to stamp tag **18** onto web **44**. Plastic web **44** travels the length of the extruder and is finally sheared into a standardized sheet dimension at the end of the line thereby defining sheet **62**. Subsequently, the sheet and tag **18** are transported to a thermoforming machine for processing.

[0045] Referring to Figure **8**, plastic web **44** is adapted in the machine and extrusion directions to produce a plastic sheet that is dimensioned to be thermoformed against four separate molding application surfaces **64a, 64b, 64c** and **64d**, illustrated separately by dashed line areas. In this manner, four pallets **4** are then produced simultaneously in the subsequent thermoforming operation. Multiple tags **18** are located on sheet **62**. On each of surfaces **64a** and **64b**, there are three tags **18**. There are also two tags **18** on surfaces **64c** and **64d**. Thus, batches of pallets **4** can be custom made for different end-uses. PC **48** interfaces with PLC **46** to instruct indexer **50** to deposit tags **18** in a selective manner. In other embodiments of the present invention, there may be multiple gantries **42** or multiple indexers **50** on one gantry **42** for depositing a variety of RFID tags **18a, 18b, 18c, 18d** and **18e** upon sheet **62**. Alternatively, a host computer **80** may interface with a LAN PC instructing further systems (not shown)

to apply a sequential array of tags **18a, 18b, 18c, 18d** or **18e** upon carrier **34** (see Figure 6) producing reel **40**, in the corresponding order to their deposition upon sheet **62**.

[0046] In the preferred order of arrangement shown in Figure 9, sheet **62** is thermoformed against a female mold located upon the lower platen of the thermoforming machine. In this manner, when sheet **62** is thermoformed, tags **18** will be encapsulated when molded sheet **68** is selectively fused to sheet **62** in the thermoforming process This creates a protective barrier around each tag **18**. It should be appreciated, however, that other sheet forming sequences may be utilized in a variety of thermoforming techniques to accomplish the present method.

[0047] One of the tags, in this example tag **18a**, interfaces with a Manufacturing Management System (hereinafter "MMS") deployed throughout the overall manufacturing infrastructure. Sheets **62, 68** and **70** (in the triple sheet method) are conveyed to a thermoforming machine RF interrogator field **72**, where a RFID tag interrogator **74** identifies and reads data stored on tags **18a**. Tags **18a** send preprogrammed data packages back to interrogator **74a**. Interrogator **74a** interfaces with LAN PC **76** connected to thermoforming machine PLC **78** interfacing through LAN to MMS host computer **80**. PLC **78** instructs machine and ancillary equipment how to process plastic sheets **62, 68** and/or **70**. PLC **76** next instructs tooling **77** how to process plastic sheets **62, 68** and/or **70**. If the MMS criteria are not met, the thermoforming process is disabled. If the MMS criteria are met, tag **18a** traverses a interrogator field **82** and tag **18a** writes and locks final data into non-volatile tag **18a** memory before pallet **4** exits the field

to enter the supply chain. Other tags **18b, 18c, 18d** and **18e** do not interface with interrogator fields **72** and **82**.

[0048] Referring now to Figure 10, pallet **4** is adapted to enhance the ability of devices **16** to survive long term pallet handling wear and tear. In particular, tines **82** of a fork lift vehicle **131** are used to move pallets **4** throughout the distribution network. When tines **82** are introduced between pallet legs **6** in order to support the weight of pallet **4** for transportation, several potentially damaging events may occur. For example, tines **82** may impact side-walls **84** of pallet **4** or legs **6**. Therefore, when systems (new and pre-existing) criteria necessitates a relatively close read range, and it is desirable to position the devices **16** in the area of side wall **84** or outside feet **86**, it would be advantageous to affix devices **16**, such as tags **18**, on lower sheet of plastic **12** away from potential areas of tine **82** impacts. Devices **16** can also be advantageously positioned on sheet **10** as may be preferred in the embodiment used, with several acceptable locations being shown. As tines **82** are introduced through pallet **4**, abrasion and shear may also occur along the path traveled by tines **82**. Accordingly, locations containing devices **16** may be reinforced to absorb and protect a device chamber **88** within which the devices **16** reside. This is illustrated in Figure 11. A variety of potential chamber designs are possible in both twin and triple sheet constructions. In twin sheet constructions, the preferred methodology is to encapsulate each device **16** between two sheets of plastic **10** and **12** in an arrangement that provides compressive, flexural, shear and anti-abrasion strength in a zone **90** contiguous to chamber **88**. A vertical side wall **92** of sheet **12** circumventing chamber **88** may incorporate vertical

details **94** and/or horizontal details **96** improving the strengthening criteria. Chamber **88** is further strengthened by top sheet **10** being locally recessed or lowered, in side-to-side elevation, so as to position the chamber away from the load bearing surface of pallet **4** and in particular the edges of packaging and objects supported thereon.

[0049] In triple sheet constructions, other pallet strengthening techniques can be used to increase the survivability of devices **16** within chamber **88**. Sheets **62, 68** and **70** are formed to substantially position chamber **88** between a top load-bearing surface **98** and a bottom tine contacting surface **100** of pallet **4** so that devices **16** are isolated from damaging events within the core of the pallet **4**. This arrangement is illustrated in Figure 12.

[0050] As understood in reference to Figure 13, devices **16**, and in particular tag **18b**, are transported through a zone **102** proximate to an interrogator **104**. Interrogator **104** interfaces with a LAN PC **106** networked to a Warehouse Management System (hereinafter "WMS"). This creates an implementation criteria that is reliable and secure for data retrieval and storage occurring while pallet **4** transits zone **102**. When the read/write distance capability of interrogator **104** is limited and necessitates a predetermined orientation of pallet **4**, some inconvenience may occur because pallet **4** will have to be rotated 180°. As this is impractical within a smooth flowing WMS, two means of intervention may be taken to prevent this undesired handling. A first means is to apply a color-coded polymeric strip **110** upon plastic sheet **70** (see Figures 9 and 12) at the time of extrusion which corresponds to the location of

devices **16**. In this manner, the pallet may be oriented by visual design for expediency. This will be discussed in further detail hereinafter.

[0051] System interference may also occur if nearby devices **16** travels outside interrogation zone **102** but through the interrogator's signal pattern **112**. Similarly, as pallet **4** is traveling through the WMS, device **16** may excite other interrogators coming within reader range. These occurrences may lead to unreliable data. In order to minimize these and other potential problems, it is preferred to encapsulate devices **16** along a center axis **114** of pallet **4**. This is shown in Figure 14. Axis **114** may progress from either the long or short side of the 48 inch by 40 inch pallet **4**. Devices **16** are positioned along axis **114** which resides in a zone **115** contiguous to a center leg **116** of pallet **4**. In this manner, tag **18** can be interrogated from either the right or left hand side of pallet **4**.

[0052] Referring to Figure 15, where a RFID system is being employed within a new setting, it is advantageous to position elements of a fixed field interrogator, such as a transit portal **117**, upon, below or well above the ground along the path transited by pallet **4**. Accordingly, an over or an under bearing RF link is provided when pallet **4** travels through an interrogator field **102b**. This arrangement also ensures that spaced apart metal tines **82** do not deflect interrogator signals, thus causing unreliable reads. In the preferred embodiment, elements of the interrogator that are positioned for an over or under bearing read pattern include an interrogator antenna assembly **118** and transmitter and receiver modules **120** and **122**, respectively, and an interrogator data processing and control module **124**, which is proximate a LAN PC **126**. With this

arrangement, improved read capability is integral to criteria for implementation reliability and security.

[0053] It may also be understood in connection with Figure 15, that PC **126** may communicate with read result display(s) **127a** positioned proximate interrogation zone **102b** in a fixed location visible to the operator controlling the movement of the pallet, or wirelessly to a display **127b** on a console **129** of a motorized pallet transporting vehicle **131**. In this manner, the system is integrated to facilitate economical movement of pallets **4** through interrogation portal **117** and distribution network.

[0054] In the present invention, a pallet and corresponding load of tagged objects, or stack of pallets, are positioned within the interrogation zone by a manually operated motorized pallet transporting vehicle. The interrogation field detects the vehicle within the zone by a triggering device. The interrogator communicates with the tags in the zone, and upon completion of this task, communicates with a visual message delivery device that is operative to instruct the driver to exit the interrogation field or pass through the portal. An LED light or the equivalent can be positioned on the drive console of the vehicle to inform the driver to stop and proceed. A stop and go light arrangement can also be positioned within the field of view of the driver to achieve the desired communication. Alternately, the host computer receiving pallet information can interface with pallet transporting vehicle by displaying on a console where the pallet is to be stored within the warehouse.

[0055] Reference should now be made to Figure 16. Another feature of the present invention employs encapsulating an interrogator communications

device **130** between the sheets forming pallet **4**. Interrogator **130** could be adapted through system architecture to take an inventory of the tags **18** or sub-set of tags **18** residing upon pallet **4**. It should be appreciated that interrogator **130** is a substantially larger device **16** than tag **18**. It may therefore be impractical to encapsulate interrogator **130** within pallet **4** in the process manner outlined above. In order to insert interrogator **130** within pallet **4**, the following methodologies would be preferred. In a twin sheet pallet construction, interrogator **130** is delivered to a selected location by means of a shuttle type delivery system that is adapted to move from a position outside the form station where apparatus loads an interrogator from a supply, to a position inside the form station, where the apparatus unloads the interrogator; it then shuttles back to load another interrogator, in between the time first sheet **10** is thermoformed and when it is sequentially fused to thermoformed second sheet **12**. The shuttle type delivery system could also be adapted to located a plurality of devices **16**, also including tags **18**, between the time first sheet **10** is molded and second sheet **12** is fused to first sheet **10** in a twin sheet construction. A shuttle system of the type may alternately be substituted with a robotic arm.

[0056] It will also be appreciated that interrogator **130** will draw a considerable amount of power for operation. Interrogator **130** is therefore active, with power supplied from a battery **132**. From time to time, interrogator battery **132** may be replaced according to a maintenance schedule contained in a data array of one of tags **18**, preferably tag **18a**. As was also the case with tags **18**, interrogator **130** will fail if delicate instruments **133**, memory and integrated circuit chips **133a**, or circuitry **135** printed on a circuit board **137** are damaged during the

high temperature and compression events of the thermoforming process. Intervention is thus required to insert battery-powered devices **16** between sheets of plastic.

[0057] Interrogator **130** is enclosed in a heat and compression resistant thermoplastic housing **134**. A housing base **134b** has a flange and threaded section **135**. Threaded section **135** accepts a thermoplastic seal and threaded plate **136**. Plate **136** is removable to replace or recharge battery **132**. Tags **18** may also be embedded in pallet **4** inside housing **134**. Alternately, tags **18** are manufactured or deposited upon circuit board **137** of interrogator **130**. As shown, battery **132** may be mounted to plate **136** adapted to reconnect the battery as the plate is threaded to a closed position. Spring terminals **138**, concentrically arranged about an axis corresponding to the rotational path of the terminals **139** on the affixed battery **132**, are developed to ensure robust connection and enduring power supply. An EMI shield **141** is provided to prevent tag reading interference; otherwise multiple pallets with goods on each pallet stored on warehouse racking may demand the use of a directional antenna **142**. Housing flange **135** is larger in diameter than a circuit board assembly. The circuit board assembly can be removed for maintenance, upgrading and recycling of pallet **4**. It is preferred that housing **134** is recyclable with the pallet when emptied. Other arrangements enclosing the devices in protective housings to withstand the rigors of thermoforming are also practical.

[0058] In order for pallet interrogator **130** to communicate with a LAN PC, a Wireless Wide Area Communication System **140** is added. System **140** can be a cellular communicator inter-operating in an open standard environment. In the

event FCC's E-911 mandate precludes utilizing cellular communications in this application (i.e. GPS), an alternative technology that can be used is wireless PC communications. The circuitry of a RF based interface PC card for a mobile PC device could be deposited upon circuit board **137**. A local area Ethernet communicator interfaces the PC card circuitry with a LAN PC, and through the LAN PC by the Internet to host computer(s) **80**. One or more circuit board antennas **142** may be slaves to several communications devices, as is battery **132**.

[0059] In the triple sheet configuration of Figure 17, housing **134** is contained in chamber **88** formed between plastic sheets **12** and **14**. After first sheet **12** is thermoformed, a shuttle type delivery system is used to deliver housing **134** to chamber **88** such that flange **135** is selectively positioned upon first sheet **12**. Concurrently, sheet **14** is thermoformed. The shuttle is extracted from the forming station, and interfacial fusion next occurs where sheets **12** and **14** are compressed together in the thermoforming operation. Housing **134** is enclosed between two sheets of plastic. Third sheet **10** is thermoformed over a third molding surface and subsequently brought into compressive contact with sheets **14** and **12**. It is not necessary that sheet **10** fuse under compression with sheet **14** at the location of interrogator chamber **88**. Before (die cut in mold) or after pallet **4** exits the thermoforming operation, an orifice on sheet **12**, adjacent threaded section **135**, is removed (by trimming) to later receive battery pack **132** affixed to plate **136**. Alternately, it may be advantageous to place housing **134** into a chamber formed by sheets **14** and **10**. It may also be advantageous to

chill the plate so that when the plate expands thermally, it produces a more robust closure.

[0060] The wireless interrogator is instructed to identify a plurality or sub-set of the RFID tags associated with articles supported upon the pallet. Thus, a pallet would be able to perform, for example, its own inventory check by arrangement.

[0061] The present invention is further advantageous over conventional systems, such as that disclosed in U.S. Patent No. 5,936,527, since inserting a wireless active interrogator in a plastic pallet of the present invention allows transportability and can be instructed to perform an operation anywhere or at any selected time within the wireless network. Examples of such a wireless network includes digital telephony, satellite communications, wireless Internet, microwave, cellular transmissions, and the like. Among other alternate embodiments of this aspect, is an optional renewable power supply device **351** (see Figure 16) that rectifies voltage generated by the antenna coils into stored energy in a battery at the interrogator in the plastic pallet or container. This effects battery size, replacement schedules, and other problems associated with wireless active interrogators. This renewable device generates energy, which recharges the associated battery, spring or other power reservoir in response to external agitational movement of the pallet during transit. The internal mechanism for the renewable device can be made in accordance with U.S. Patent No. 4,500,213 entitled "Ultra-Flat Self Winding Watch" which issued to Grimm on February 19, 1985, and is incorporated by reference herein. The internal circuitry is shown in Figure 24 wherein the capacitor act as the power storage reservoir. Renewable

device **351** employs an oscillating weight **361**, rotor **363**, top generating coil block **365**, circuit block **367** with an integrated circuit **370**, bottom generating coil **369**, capacitor/condenser **371** and battery/power source **373**. Battery **373** is electrically connected to the communications device which includes an active tag **375**, an interrogator **377** and a communicator **379**.

[0062] Moreover, the wireless active interrogators could also be positioned within a molded structure forming part of the plastic pallet. A battery supply information field could be part of the manufacturing memory tag or third party pallet management memory array as preventative maintenance schedule field.

[0063] Yet another advantage of the aspect of encapsulating a plurality of RFID devices within the structure of a thermoformed pallet is that the same pallet can be tracked through different networks that interface according to differing substantially proprietary protocols. There are several popular data encoding methods, at least three data modulation standards and a handful of proprietary anticollision backscatter formats. It is unlikely that in the future, one device will be able to interface will all deployed systems because an open standard for interoperability has not overcome issues with respect to proprietary technologies. There is also a range of operating environments and computer operating system platforms to interface with. A combination of devices within one product that enables functionality at many locations with pre-existing system infrastructures will help propel the plastic pallet through the distribution system. Notwithstanding, one tag device with several proprietary circuits could be coupled with one or more memory chips, and one antenna coil.

[0064] According to yet another aspect of the invention, one or a plurality of RFID devices are provided within a single plastic pallet. For example, one such tag may be dedicated to manufacturing, material and recycle information storage. One tag may be specifically adapted for pallet tracking within the distribution system. The pallet may also host a third RFID device specified by third parties for specialized inventory tracking activities within closed-loop or associated distribution networks. A fourth tag may be developed to consolidate the data arrays of several tags transported upon the pallet for more efficient data compression and transfer. A fifth tag may be adapted for interfacing with the RFID systems deployed by the trucking industry. Accordingly, one or more RFID devices may be embedded within one pallet to facilitate one or more operations according to different implementation objectives that ultimately increase the efficiency of plastic pallets.

[0065] According to this additional preferred aspect of the present invention, one RFID device is used during the pallet manufacturing process. A relatively simple, programmable passive RFID device that provides a bi-directional interface for one-time programming and multiple readings of the memory is used. The tag on the plastic sheet is interrogated to instruct the PLC of the thermoforming machine how the sheet is to be processed. In one such example, even though the standard 48 inch by 40 inch wooden pallet is designed to carry 2,800 pounds, the GMA claims approximately 30% of the unit loads weigh less than 1,000 pounds, and 66% of unit loads weight under 2,000 pounds. Accordingly, the preferred thermoforming method may be used to produce a select range of standard plastic pallets, that are produced using different plastic

formulations and processing guidelines, to meet different distribution system needs. The machine PLC may then be instructed to communicate to the tooling to instruct the tooling how to process the successive sheets. The thermoforming machine, production tooling and sheet materials thus interface with each other to recognize, synchronize, authenticate, implement and record manufacturing results to a manufacturing biased host computer. The memory array of the proposed device is limited to read-only data transmission and is disabled from accepting further programming or erasing instructions once the pallet is made but before the tagged pallet enters the pallet supply stream. The memory array of the manufacturing related RFID device will contain information pertaining to manufacture date, serial number, load bearing capabilities, operating temperatures, material composition, repair instructions, expiration date, recycling requirements, ownership, ISO certificates and the like. The data contained in the array could be tailored toward the needs of a third party pallet rental/leasing company, which can schedule and perform RFID and pallet maintenance.

[0066] This embodiment is explained in more detail as follows, with reference to Figure 18. An end use customer requests a custom made final product by communicating his specifications manually to a sales office or through a remote electrical communications interface, such as the internet. The control system computer will use predetermined algorithms and look up tables to automatically determine the optimum manufacturing criteria for these customer specifications. The determined manufacturing criteria is subsequently communicated to the tag manufacturing plant's local host computer.

[0067] The tags are sequentially deposited upon a roll at which point the tags receive selective data information which is pre-programmed or stored in the memory of each tag. The pre-formed sheets, containing the RFID tag, are subsequently conveyed to the thermoforming plant or machinery for processing into end products, shown in the figure as product A and product B.

[0068] The RFID tag on the sheet traverse and travel through the interrogation field prior to entry of the sheet into the thermoforming machine. Data previously stored and programmed into the RFID tag memory is thereby communicated to the thermoforming machine PLC attached to the interrogator. The PLC thereby analyzes the received data and adjusts the manufacturing operation and machinery as predetermined for the specific data criteria analyzed.

[0069] For example, fire retardant fillers in the plastic sheet require a longer period of time for heating in the ovens. Thus, data regarding the presence of fire retardant materials, which has been previously programmed or stored in the RFID tag memory, instructs the PLC of its presence and the PLC then controls the machinery to provide increased heat in the ovens for the specific sheet about to enter the ovens. The next sheet to be processed may not have a fire retardant filler and thus the PLC will accordingly vary the machinery and processing operation to reduce the oven heat applied to that subsequent sheet to be processed. In another example, an end product may be desired to have a metal inserted frame for increased load bearing strength. When the interrogator receives this information from the RFID tag attached to a sheet to be processed, the PLC operating the processing machinery will then instruct an auxiliary input A machine to insert a metal frame between a pair of the sheets being processed.

This can be done by a robotic arm or through other automation. The process is completed according to the preprogrammed manufacturing instructions in the machinery PLC, as altered or varied by data stored in the RFID tag for each sheet being processed. After completion, the PLC communicates the record of completion to a network computer for billing purposes and other statistical process control information.

[0070] Still according to another aspect of the present invention, one or more RFID devices are used to identify, locate and track a pallet within the distribution network throughout the pallet's life cycle. In the manner, computer based tools can be utilized to increase the velocity of the pallet through the system. In other words, the pallets are managed as an asset rather than an expense. The pallet is tracked using a more complex programmable RFID device that provides a variety of operating modes (single tag/multiple tag environments), including multiple write and read (EEPROM) capabilities. Tagged pallets traverse interrogation fields distributed throughout the distribution network to record the pallet's progress through the distribution system. The RFID devices include anticollision modulation options to resolve backscatter when multiple tags are in the same interrogation fields. Automatic pallet material handling equipment is upgraded to accommodate readers and communicators. Supply chain management and control of the movement of pallets through the distribution system are facilitated with real-time data input from the integrated RFID system. Host, interrogator and tag interface according to various implementation criteria, such as last scan time & date, movement order number field, "from" field, "to" field, shipper field, pallet rental release field, and pallet return instructions. RFID

technology provides a two-way flow of information between the pallet and the system server to help propel the pallet through the distribution system. The RFID devise may also carry its own electronic manifest. A more efficient use of plastic pallets will reduce the total number of pallets required by the over all distribution system.

[0071] According to a further feature of the present invention, each RFID device that is contained in the pallet may be developed to operate on different radio frequencies (13.56 megahertz to 2.45 gigahertz) in order to optimize system performance and minimize the cost of interrogators and tags. Each device may use a different coding waveform algorithm to reduce data recovery errors, bandwidth problems, synchronization limitations and other system design and cost considerations. For example, the pallet manufacturer does not need interrogation systems interfacing with the tracking systems, and vice versa. Thus, a less elaborate and costly RFID system is needed by the thermoforming manufacturer to deploy RFID systems. Similar tag device transmissions may be echeloned according to prescribed system criteria or other pallet management tools or model algorithms.

[0072] As Faraday's law and Lenz's law are well known, it is also understood that the parallel orientation, and the distance between the reader and tag antenna coils in respect of each other are important for the successful operation of passive RFID devices in particular. Read range is lower in higher frequency passive RFID devices. Furthermore, it is understood that induction is maximized when the antenna coils are perpendicular to the direction of the radio frequency signal. Therefore, another feature of the present invention provides for

encapsulation of RFID devices within the structure of the plastic pallet. In one embodiment, an interrogator is contained in a vertical freestanding structure off to the side of the path traveled by the RFID device. Accordingly, the antenna coils located in the interrogator and pallet are vertically oriented in approximate parallel condition to facilitate a proper signal transmission. In another embodiment, an interrogator is placed upon or under ground along the path traveled by the pallet, or alternatively suspended from above. In such an arrangement, it is advantageous to orient the respective antenna coils substantially horizontal in an approximate parallel condition to facilitate induction. These later arrangements would be difficult to duplicate and implement with wooden pallets because water absorbed by the wood would impede or reflect the RF signal away from the tag antenna.

[0073] A further preferred method of attaching RFID tags to polymeric sheets is as follows, with reference to Figure 19. A polyethylene or polypropylene sheet **501** is created by an extruder **503** and a pair of opposed rolls **505**. The continuously created sheet is then fed through an indexer **507** at which point RFID tags **509** are fed from tag rolls **511** which are deposited in a spaced fashion upon an upper surface of sheet **501**. A narrow roll of polyethylene or polypropylene film **513** is simultaneously unwound from a film roll **517** and then compressed by a spring biased application roller **519** upon sheet **501** and covering each tag **509**. The film is thermally bonded to sheet **501** by compression of heated spring biased application roller **519**. The continuous sheet **501** is subsequently sheared or cut into separate preformed sheets **521** by a shearing machine **523**.

[0074] It is alternately envisioned that the film is colored so that it can be used to indicate tag location inside of a pallet for correct orientation to provide accurate readings as previously disclosed. For example, a plurality of colored films may be applied to denote RFID tag implementation criteria. For example, Figures 20 and 21 show a four-up sheet wherein one operation yields four formed parts; in other words, four pre-formed sheets, with their respective RFID tags, are not severed until after thermoforming. Film **513** is shown in two distinct and parallel, elongated locations covering RFID tags **509** upon the four-up sheet **521**. Film **513** further protects the underlying tags **509** as a leading edge **531** of a subsequently severed sheet is angularly moved along a lower sheet **521** during stacking.

[0075] Another preferred embodiment application of the thermoforming and communications device technology is shown in Figure 22. In this embodiment, a gasoline fuel tank **601**, such as those used with an automotive, motorcycle, all-terrain vehicle, airplane, boat or other motorized vehicle, is made using twin or triple sheet thermoforming. Tank **601** is made of three, three-dimensionally formed sheets of plastic, **603**, **605** and **607**, respectively, which are all joined together during processing. A bottom hollow section **609** operably contains a liquid, such as gasoline fuel. A top hollow section **611** contains a fuel filler, filter, and other standard devices **613** necessary for the operation of tank **601**.

[0076] A communications device **621** is attached to an inside surface of sheet **607** within top hollow section **611** prior to thermoforming, as was previously disclosed herein with the pallet manufacturing. As the fuel is removed for engine

combustion, environmentally hazardous gases are left to fill the space unoccupied by the fuel. Top hollow section **611** acts as a reservoir that contains the harmful gases that would otherwise escape through the devices **613** into the environment. The devices **613** can also recirculate the gas back into lower hollow sections **609**, in a conventional manner. An instrument section of communications device **621** is operable to inspect and monitor the barrier performance of top hollow section **611** to ensure compliance with governmental regulations. When the vehicle is inspected, the data generated and stored by the instrument of device **621** is then conveyed through radio frequency communications to an external monitoring device operated by the governmental regulating authority for inspection purposes. The instrument section of device **621** can be battery activated in an active manner to provide regular intervals of inspection, can be passive to receive power when externally interrogated, or can be triggered one time when a predetermined threshold is met.

[0077] A further preferred application of the present invention is shown in Figure 23. A bulk container **701** operably carries a hazardous material therein. For example, a two-part polyurethane container system is made from three sheets **703**, **705** and **707** which are thermoformed and joined as previously disclosed herein to provide container **701** with two reservoirs **709** and **711**. Flange plates **713** and **715,** having threads, are formed onto container **701** to receive metering pump elements (not shown). These flange plates are made in accordance with those disclosed for battery replacement in the pallets. Pockets or receptacles **717** are created between adjacent internal sheets **703** and **705** at an overlapping margin to receive RFID tag devices. The RFID tags perform a

range of functions which include recording of chemical formulas of materials contained within reservoirs **709** and **711**, storage of safety data for storing, clean up information, worker injury information (such as that traditionally contained on a material safety data sheet), temperatures, thermal shock, and for disposal instructions. This data can later be interrogated by an external interrogator or the like.

[0078] While the preferred embodiment of a thermoformed pallet having a radio frequency device has been disclosed, it should be appreciated that other variations may be employed. For example, with a shuttle type delivery system and methodology, the gantry and laminator apparatus are not required. There are several other methodologies that may be used to practice the useful purposes of embedding sophisticated communications and other technological devices within the structure of plastic pallet **2**. Furthermore, analog or solid state circuitry can be employed instead of the microprocessors, integrated circuits and computers disclosed. There are a number of different reinforcing structures that can be molded into two or more sheets of plastic to reinforce the area around devices **16**. It is not necessary to form a complete chamber in plastic, so long as device **16** remains in the areas developed to protect the device from thermoforming shock, and operating wear and tear. It is also understood that access to the devices may be from the top or bottom in the wide variety of pallets contemplated in the present methodology. Furthermore, the RFID tags can also be attached to other heat and pressure formable sheets, such as cardboard, fiberglass, or the like, prior to three dimensional forming of the sheets. Additionally, the RFID tags and other electrical communications devices can be

employed to monitor food conditions within a food container. While various materials have been disclosed, it should be appreciated that other materials can be employed. It is intended by the following claims to cover these and any other departures from the disclosed embodiments which fall within the true spirit of this invention.